FORM PTO-1390 (REV. 11-2000) U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER	U.S. APPLICATION NO. (If known, see 37 CFR 1.5)
2611-0148P	09/857461

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/JP00/07312	October 20, 2000	October 29, 1999

TITLE OF INVENTION

METHOD AND DEVICE FOR COMMUNICATION

APPLICANT(S) FOR DO/EO/US

MATSUMOTO, Wataru; MIYATA, Yoshikuni

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39 (1).
4. ☐ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau). WO 01/33719
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☒ is transmitted herewith.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4)
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 20. below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98-International Search Report (PCT/ISA/210) w/ documents
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
14. ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821-1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information:
    1.) Nine (9) sheets of Formal Drawings

U.S. APPLICATION NO (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
09/857461 NEW	PCT/JP00/07312	2611-0148P

21. ☒ The following fees are submitted:	CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5):		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO. **$1,000.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$860.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO. **$710.00**		
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$690.00**		
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4). **$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 860.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$ 0	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total Claims	13 - 20 =	0	X **$18.00**	$ 0	
Independent Claims	5 - 3 =	2	X **$80.00**	$ 160.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)		None	+ **$270.00**	$ 0	
			TOTAL OF ABOVE CALCULATIONS =	$ 1020.00	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				$ 0	
			SUBTOTAL =	$ 1020.00	
Processing fee of **$130.00** for furnishing the English translation later than ☐20 ☐30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$ 0	
			TOTAL NATIONAL FEE =	$ 1020.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$ 40.00	
			TOTAL FEES ENCLOSED =	$ 1060.00	
			Amount to be: refunded	$	
			charged	$	

a. ☒ A check in the amount of $ **1060.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account. No. _____ in the amount of $_____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 02-2448.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

Send all correspondence to:
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Date: June 5, 2001

By _____
John A. Castellano, #35,094

/cqc

IN THE U.S. PATENT AND TRADEMARK OFFICE

Applicant:	MATSUMOTO, Wataru et al.	Conf.:	
Int'l. Appl. No.:	PCT/JP00/07312		
Appl. No.:	New	Group:	
Filed:	June 5, 2001	Examiner:	
For:	METHOD AND DEVICE FOR COMMUNICATION		

PRELIMINARY AMENDMENT

BOX PATENT APPLICATION
Assistant Commissioner for Patents
Washington, DC 20231

June 5, 2001

Sir:

The following Preliminary Amendments and Remarks are respectfully submitted in connection with the above-identified application.

AMENDMENTS

IN THE SPECIFICATION:

Please amend the specification as follows:

Before line 1, insert --This application is the national phase under 35 U.S.C. § 371 of PCT International Application No. PCT/JP00/07312 which has an International filing date of October 20, 2000, which designated the United States of America and was not published in English.--

Please substitute the following paragraph for the first full paragraph on page 17:

--In the decoder shown in Fig. 1(b), reference numeral 11 denotes a first decoder for calculating the logarithm likeliness ratio from receiving signal: Lcy (corresponding to receiving

signals: V_0, V_1, W_0 and W_1, as will be described later), 12 and 16 are adders. Reference numerals 13 and 14 denote interleavers. Reference numeral 15 denotes a second decoder for calculating the logarithm likeliness ratio from the receiving signal: Lcy (corresponding to receiving signals: V_0, V_1, W_0 and W_1, as will be described later). Reference numeral 17 denotes a deinterleaver. Reference numeral 18 denotes a first judging device for judging the output of the second decoder 15 to output an estimated value of the original information bit list, and reference numeral 19 denotes a second judging device for hard-judging the Lcy (corresponding to receiving signals: V_2..., W_2..., as will be described later) to output an estimated value of the original information bit list.--

REMARKS

The specification has been amended to provide a cross-reference to the previously filed International Application. The specification has also been amended to correct a typographical error. Entry of the present amendment and favorable action on the above-identified application are earnestly solicited.

Attached hereto is a marked-up copy of the changes made to the application by this Amendment.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 02-2448 for any additional fees required under 37 C.F.R. § 1.16 or under 37 C.F.R. § 1.17; particularly, extension of time fees.

Respectfully submitted,

BIRCH, STEWART, KOLASCH & BIRCH, LLP

By _____
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JAC/cqc
2611-0148P

Attachment: Version With Markings Showing Changes Made

(Rev. 01/22/01)

VERSION WITH MARKINGS SHOWING CHANGES MADE

The specification has been amended to provide cross-referencing to the International Application. The specification has also been amended as follows:

In the decoder shown in Fig. 1([a]b), reference numeral 11 denotes a first decoder for calculating the logarithm likeliness ratio from receiving signal: Lcy (corresponding to receiving signals: V_0, V_1, W_0 and W_1, as will be described later), 12 and 16 are adders. Reference numerals 13 and 14 denote interleavers. Reference numeral 15 denotes a second decoder for calculating the logarithm likeliness ratio from the receiving signal: Lcy (corresponding to receiving signals: V_0, V_1, W_0 and W_1, as will be described later). Reference numeral 17 denotes a deinterleaver. Reference numeral 18 denotes a first judging device for judging the output of the second decoder 15 to output an estimated value of the original information bit list, and reference numeral 19 denotes a second judging device for hard-judging the Lcy (corresponding to receiving signals: V_2..., W_2..., as will be described later) to output an estimated value of the original information bit list.

SPECIFICATION

TITLE OF THE INVENTION

Method of and device for communication

TECHNICAL FIELD

The present invention in general relates a method of and device for communication that use a multi-carrier modem system. More particularly, this invention relates to a communication device which realizes data communication through the existing communication lines by using a method such as the DMT (Discrete Multi-Tone) modem system and the OFDM (Orthogonal Frequency Division Multiplex) modem system and a communication method capable of realizing such a communication device. However, the present invention is not intended to be limited to the communication device for carrying out data communication through the DMT modem system, and is applicable to any communication device for carrying out cable communication and radio communication through normal communication lines by using the multi-carrier modem system and a single carrier modem system.

BACKGROUND ART

The conventional communication methods will be explained below. For example, in the wide band CDMA (W-CDMA:

Code Division Multiple Access) using the SS (Spread Spectrum) system, turbo codes have been proposed as error-correction codes that greatly exceed convolutional codes in their performances. In the turbo code, a list formed by interleaving an information list is encoded in parallel with a known coding list, and the turbo code is one of the error-correction codes that have attracted the greatest public attention at present, and is said to provide characteristics close to Shannon limit. In the above-mentioned W-CDMA, since the performances of the error-correction code give great effects on the transmission characteristics in the voice transmission and data transmission, the application of the turbo code makes it possible to greatly improve the transmission characteristics.

Operation of transmitting and receiving systems of the conventional communication device using the turbo code will be explained in detail below. Fig. 8 is a drawing that shows the construction of a turbo encoder used in the transmitting system. In Fig. 8(a), reference numeral 101 denotes a first recursive system convolutional encoder that subjects an information list to a convolutional encoding process to output redundant bits. Reference numeral 102 denote an interleaver, and reference numeral 103 denote a second recursive system convolutional encoder that subjects

the information list that has been switched by the interleaver 102 to a convolutional encoding process to output redundant bits. Fig. 8(b) is a drawing that shows the inner structures of the first recursive system convolutional encoder 101 and the second recursive system convolutional encoder 103, and the two recursive system convolutional encoders are encoders that only output redundant bits respectively. Moreover, the interleaver 102, which is used in the turbo encoder, randomly switches information bit lists.

The turbo encoder, which is arranged as described above, simultaneously outputs an information bit list: x_1, a redundant bit list: x_2 obtained by encoding the information bit list through the operation of the first recursive system convolutional encoder 101, and a redundant bit list: x_3 obtained by encoding the information bit list that has been interleaved through the operation of the second recursive system convolutional encoder 103.

Fig. 9 is a drawing that shows the construction of the turbo decoder that is used in the receiving system. Reference numeral 111 denotes a first decoder that calculates a logarithm likelihood ratio from a receiving signal: y_1 and a receiving signal: y_2. Reference numerals 112 and 116 denote adders, and reference numeral 113 and 114 denote interleavers. Reference numeral 115 denotes a second

decoder that calculates a logarithm likelihood ratio from a receiving signal: y_1 and a receiving signal: y_3. Reference numeral 117 denotes a deinterleaver, and reference numeral 118 denotes a judging device for judging the output of the second decoder 115 to output an estimated value of the original information bit list. The receiving signals: y_1, y_2, y_3 are signals that are formed by allowing the information bit list: x_1 and the redundant bit lists: x_2, x_3 to include influences from noise and phasing in the transmission path.

In the turbo decoder that is arranged as described above, first, the first decoder 111 calculates the logarithm likelihood ratio: $L(U_k)$ (where k refers to the time) from a received signal: y_{1k} and a received signal: y_{2k}. In this case, the logarithm likelihood ratio: $L(U_k)$ is represented by the following equation:

$$L(u_k)=y_{1k}+La(u_k)+Le(u_k)$$

$$=Ln\ \frac{Pr(x_{1k}'=1|\{Y\})}{Pr(x_{1k}'=0|\{Y\})} \quad \cdots\cdots \quad (1)$$

Here, $Le(U_k)$ represents external information, $La(U_k)$ represents preliminary information that is external information preceding by one, $P_r(x_{1k}' = 1 | \{Y\})$ represents the probability of an estimated information bit upon receipt of the entire list {Y} of the received signals: x_{1k}' being 1 and , $P_r(x_{1k}' = 0 | \{Y\})$ represents the probability of an

estimated information bit upon receipt of the entire list {Y} of the received signals: x_{1k}' being 0. In other words, equation (1) finds the probability of the estimated information bit: x_{1k}' becoming 1 with respect to the probability of the estimated information bit: x_{1k}' being 0.

Next, the adder 112 calculates external information to be given to the second decoder 115 from a logarithm likelihood ratio that is the result of the above-mentioned calculation. Based upon the above-mentioned equation (1), the external information: Le (U_k) is represented by the following equation:

$$Le(U_k) = L(U_k) - y_{1k} - La(U_k) \quad \ldots (2)$$

Since no preliminary information has been given at the time of the first decoding process, $La(U_k) = 0$.

In the interleavers 113 and 114, in order to make the received signal: y_{1k} and the external information: Le (U_k) coincident with the time of the received signal: y_3, the signals are re-arranged. Then, in the same manner as the first encoder 111, based upon the received signal: y_1 and the received signal: y_3 as well as the external information: $Le(U_k)$ preliminarily calculated, the second decoder 115 calculates a logarithm likelihood ratio: $L(U_k)$. Thereafter, in the same manner as the adder 112, the adder 116 calculates the external information $Le(U_k)$ by using equation (2). At

this time, the external information, rearranged by the interleave 117, is fed back to the first decoder 111 as the preliminary information: $La(U_k)$.

Finally, in the turbo decoder, the above-mentioned processes are repeatedly executed predetermined times so that it is possible to calculate a logarithm likelihood ratio with higher precision, and the judgment device 118 makes a judgment based upon this logarithm likelihood ratio, thereby estimating the bit list of the original information. More specifically, for example, the logarithm likelihood ratio shows that "$L(U_k) > 0$", the estimated information bit: x_{1k}' is judged as 1, while it shows that "$L(U_k) \leqq 0$", the estimated information bit: x_{1k}' is judged as 0.

In this manner, in the conventional communication method, by using the turbo code as the error-correction code, even when the signal point-to-point distance becomes closer as the modulation system is multi-valued, it becomes possible to greatly improve the transmitting characteristics in the voice transmission and data transmission, and consequently to obtain characteristics superior to the known convolutional codes.

However, in the above-mentioned conventional communication method, in order to carry out an error correction with high precision, the turbo encoding process is carried out on all the information lists on the

transmitting side, and on the receiving side, all the encoded signals are decoded, and a soft-judgment is then executed thereon. More specifically, for example, in the case of 16 QAM, a judgment is made with respect to all the 4-bit data (0000 to 1111: 4-bit constellation), and in the case of 256 QAM, a judgment is made with respect to all the 8-bit data. Therefore, conventionally, the application of the conventional communication method that carries out judgments on all the data as described above causes a problem of an increase in the amount of calculations in the encoder and decoder in response to the multi-valued levels.

Therefore, the object of the present invention is to provide a communication device and a communication method for such a device, which is applicable to any communication system using the multi-carrier modem system and the single-carrier modem system, and makes it possible to achieve a reduction in the amount of calculations and to provide a good transmitting characteristics in the same manner as the conventional device, even when there is an increase in the constellation due to multi-valued levels.

DISCLOSURE OF THE INVENTION

The communication device according to one aspect of this invention, which uses turbo codes as error-correction codes, is provided with a turbo encoding unit (corresponding

to a turbo encoder 1 in an embodiment which will be described later) which carries out a turbo encoding process on lower bits of a predetermined number in transmission data to output information bits in accordance with the predetermined number and first and second redundant bits that have been convolutionally encoded in different sequences; a computing unit (corresponding to a conversion 2) which carries out calculations for uniforming error-correction capabilities on the respective information bits by using the information bits of the predetermined number and the redundant bits to output the results of the calculations and the other bits in the transmission data as the results of the encoding process; a first decoding unit (corresponding to a first decoder 11 and an adder 12) which extracts the information bits and the first redundant bits from the lower bits of the predetermined number in the received signal, and makes a soft-judgment based upon the results of the extraction and a soft judgment output that is an output preceding by one given as preliminary information (in some cases, not given); a second decoding unit (corresponding to a second decoder 15, an interleavers 13 and 14, an adder 16 and a deinterleaver 17) which extracts the information bits and the second redundant bits, makes a soft-judgment based upon the results of the extraction and the soft-judgment output from the first decoding unit, and informs the first decoding

unit of the results thereof as the soft-judgment output preceding by one; a first judging unit (corresponding to a first judging device 18) which executes the soft-judgment by the first decoding unit and the second decoding unit a predetermined times repeatedly, and then estimates the original information bit based upon the soft-judgment output of the second decoding unit; and a second judging unit (corresponding to a second judging device 19) which makes a hard-judgment on the other bits in the received signal to estimate the original information bits.

Furthermore, the turbo encoding unit is provided with a deinterleave processing unit (corresponding to a deinterleaver 25) for carrying out a de-interleaving process on one group of the redundant bits that have been encoded after the interleave process to output the respective information bits and the redundant bits with the times being coincident with each other.

Furthermore, Reed Solomon codes and turbo codes are used combinedly, and on the transmitting side, the turbo encoding is carried out after the Reed Solomon encoding, while on the receiving side, the Reed Solomon codes are decoded after decoding the turbo codes.

The communication device according to another aspect of this invention has an encoder that uses turbo codes with the interleave process being incorporated into the encoding

process. This encoder is provided with a turbo encoding unit (corresponding to a turbo encoder 1 in an embodiment which will be described later) which receives transmission data constituted by a plurality of bits, and carries out a turbo encoding process on lower bits of a predetermined number in transmission data to output information bits in accordance with the predetermined number, first redundant bits that have been obtained by convolutionally encoding the information bits and second redundant bits that have been obtained by convolutionally encoding the information bits after the interleave process; and a computing unit (corresponding to a conversion 2) which carries out calculations for uniforming error-correction capabilities on the respective information bits by using the information bits of the predetermined number and the redundant bits, in such a manner that the results of the calculations and the other bits in the transmission data are outputted as the results of the encoding process.

Furthermore, the turbo encoding unit is provided with a deinterleave processing unit (corresponding to a deinterleaver 25) for carrying out a de-interleaving process on the second redundant bits so that the respective information bits, the first redundant bits and the second redundant bits that have been subjected to the de-interleaving process are outputted with the times being

coincident with each other.

The communication device according to still another aspect of this invention has an encoder that uses turbo codes with the interleave process being incorporated into the encoding process. This encoder is provided with a turbo encoding unit which receives transmission data constituted by a plurality of bits, and carries out a turbo encoding process on lower bits of a predetermined number in transmission data to output information bits in accordance with the predetermined number, first redundant bits that have been obtained by convolutionally encoding the information bits and second redundant bits that have been obtained by convolutionally encoding the information bits after the interleave process, in such a manner that in addition to the respective information bits and the first and second redundant bits, the other bits in the transmission data are outputted as the results of the encoding process.

Furthermore, Reed Solomon codes and turbo codes are used combinedly, and the turbo encoding is carried out after the Reed Solomon encoding.

The communication device according to still another aspect of this invention has a decoder that decodes a received signal that has been turbo encoded by using a soft judgment. This decoder is provided with a first decoding unit (corresponding to a first decoder 11 and an adder 12) which

extracts information bits and first redundant bits that have been convolutionally encoded from the lower bits of the predetermined number in the received signal, and makes a soft-judgment based upon the results of the extraction and a soft judgment output that is an output preceding by one given as preliminary information (in some cases, not given); a second decoding unit (corresponding to a second decoder 15, an interleavers 13 and 14, an adder 16 and a deinterleaver 17) which extracts the information bits in accordance with the number of outputs on the encoder side and the second redundant bits that have been convolutionally encoded in a method different from the first redundant bits from the lower bits in the predetermined number in the received signal, makes a soft-judgment based upon the results of the extraction and the soft-judgment output from the first decoding unit, and informs the first decoding unit of the results thereof as the soft-judgment output preceding by one; a first judging unit (corresponding to a first judging device 18) which executes the soft-judgment by the first decoding unit and the second decoding unit a predetermined times repeatedly, and then estimates the original information bit based upon the soft-judgment output of the second decoding unit; and a second judging unit (corresponding to a second judging device 19) which makes a hard-judgment on the other bits in the received signal

to estimate the original information bits.

Furthermore, when Reed Solomon codes and turbo codes are used combinedly on the transmitting side, the Reed Solomon codes are decoded after decoding the turbo codes.

The communication method according to still another aspect of this invention, which uses turbo codes as error-correction codes, is provided with a turbo encoding step of carrying out a turbo encoding process on lower bits of a predetermined number in transmission data to output information bits in accordance with the predetermined number and first and second redundant bits that have been convolutionally encoded in different sequences; a computing step of carrying out calculations for uniforming error-correction capabilities on the respective information bits by using the information bits of the predetermined number and the redundant bits to output the results of the calculations and the other bits in the transmission data as the results of the encoding process; a first decoding step of extracting the information bits and the first redundant bits from the lower bits of the predetermined number in the received signal so as to make a soft-judgment based upon the results of the extraction and a soft judgment output that is an output preceding by one given as preliminary information (in some cases, not given); a second decoding step of extracting the information

bits and the second redundant bits so as to make a soft-judgment based upon the results of the extraction and the soft-judgment output from the first decoding step, thereby informing the first decoding unit of the results thereof as the soft-judgment output preceding by one; a first judging step of executing the soft-judgment by the first decoding step and the second decoding step a predetermined times repeatedly, and then estimating the original information bit based upon the soft-judgment output of the second decoding step; and a second judging step of making a hard-judgment on the other bits in the received signal to estimate the original information bits.

Furthermore, the turbo encoding step is provided with a deinterleave processing step of carrying out a de-interleaving process on one group of the redundant bits that have been encoded after the interleave process to output the respective information bits and the redundant bits with the times being coincident with each other.

Furthermore, Reed Solomon codes and turbo codes are used combinedly, and on the transmitting side, the turbo encoding is carried out after the Reed Solomon encoding, while on the receiving side, the Reed Solomon codes are decoded after decoding the turbo codes.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a drawing that shows constructions of an encoder and a decoder that are used in a communication device in accordance with the present invention; Fig. 2 is a drawing that shows a construction of a transmitting system of a transmitter in accordance with the present invention; Fig. 3 is a drawing that shows a construction of a receiving system in accordance with the present invention; Fig. 4 is a drawing that shows a tone construction in a multi-carrier modem system and a construction of an encoder that is applicable to a 4-bit constellation; Fig. 5 is a drawing that shows a layout of signal points in various digital modulations; Fig. 6 is a drawing that shows a circuit construction of a turbo encoder 1; Fig. 7 is a drawing that shows a difference in bit error rates; Fig. 8 is a drawing that shows a construction of a conventional turbo encoder; and Fig. 9 is a drawing that shows a construction of a conventional turbo encoder.

BEST MODE FOR CARRYING OUT THE INVENTION

Preferred embodiments of the method of and device for communication in accordance with the present invention will be explained below with reference to the accompanying drawings. However, the present invention is not intended to be limited by these embodiments.

Fig. 1 is a drawing that shows constructions of an

encoder (a combination of a turbo encoder and a conversion) and a decoder (a combination of a turbo decoder and a hard judging device) used in a communication device in accordance with the present invention in which. More specifically, Fig. 1(a) shows the construction of the encoder, and Fig. 1(b) shows the construction of the decoder according to this embodiment. In the communication device in accordance with the present embodiment, both of the constructions of the encoder and decoder are installed so that it is possible to provide a data error-correction capability with high precision, and consequently to obtain a superior transmitting characteristics in data communication and voice communication. Here, in the present embodiment, for convenience of explanation, both of the constructions are provided; however, for example, of the two devices, only the encoder may be installed in a transmitter, or only the decoder may be installed in a receiver.

Moreover, in the encoder in Fig. 1(a), reference numeral 1 denote a turbo encoder that uses turbo codes as error-correction codes so as to provide a performance close to the Shannon limit and 2 is a conversion for converting data received from the turbo encoder 1. In the turbo encoder 2, for example, with respect to an input of two-bit information bits, two-bit information bits and two-bit redundant bits are outputted, and in the conversion 2, with

respect to the received 4-bit data, calculations are carried out so as to uniform the correction capabilities with respect to the information bits on the receiving side.

In the decoder shown in Fig. 1(a), reference numeral 11 denotes a first decoder for calculating the logarithm likeliness ratio from a receiving signal: Lcy (corresponding to receiving signals: v_0, v_1, w_0 and w_1, as will be described later), 12 and 16 are adders. Reference numerals 13 and 14 denote interleavers. Reference numeral 15 denotes a second decoder for calculating the logarithm likeliness ratio from the receiving signal: Lcy (corresponding to receiving signals: v_0, v_1, w_0 and w_1, as will be described later). Reference numeral 17 denotes a deinterleaver. Reference numeral 18 denotes a first judging device for judging the output of the second decoder 15 to output an estimated value of the original information bit list, and reference numeral 19 denotes a second judging device for hard-judging the Lcy (corresponding to receiving signals: $v_{2\cdots}$, $w_{2\cdots}$, as will be described later) to output an estimated value of the original information bit list.

Prior to explaining the operations of the encoder and decoder, an explanation will be briefly given of the basic operation of the communication device in the present invention by reference to Figures. For example, with respect to the cable-type digital communication system for

carrying out data communication by using the DMT (Discrete Multi Tone) modem system, there are xDSL communication systems including an ADSL (Asymmetric Digital Subscriber Line) communication system that executes a high-speed digital communication with several mega bits/second by using the existing telephone lines and an HDSL (high-bit-rate Digital Subscriber Line) communication system. Here, these systems are standardized in T1.413 of the ANSI, etc. In the explanation of the present embodiment, for example, a communication device that is applicable to the ADSL is used.

Fig. 2 is a drawing that shows the construction of a transmitting system of a communication device in accordance with the present invention. In this transmitting system, the transmission data is multiplexed by a multiplex/synch control (corresponding to a MUS/SYNC CONTROL in the Figure) 41, and error-correction codes are added to the transmission data that has been multiplexed in cyclic redundancy checks (corresponding to CRC: Cyclic Redundancy Checks) 42, 43, and FEC-use codes are added thereto and a scrambling process is also applied thereto in forward error corrections (corresponding to SCRAM & FEC) 44, 45.

There are two paths from the multiplex/synch control 41 to a tone ordering 49, and one is an interleaved data buffer path containing the interleave 46, and the other is a fast data buffer path that does not contain the interleave

46; thus, for example, the interleaved data buffer path for executing an interleaving process has a greater delay.

Thereafter, the transmission data is subjected to a rate converting process in rate converters (corresponding to RATE-CONVERTORS) 47, 48, and then subjected to a tone ordering process in the tone ordering (corresponding to TONE ORDERRING) 49. Based upon the transmission data after the tone ordering process, constellation data is formed in a constellation encoder/gain scaling (corresponding to CONSTELLATION AND GAIN SCALING) 50, and this is subjected to an inverse Fast Fourier transform in an inverse Fast Fourier transform section (corresponding to IFFT: Inverse Fast Fourier transform) 51.

Finally, after the Fourier transform, the parallel data is converted to serial data in an input parallel/serial buffer (corresponding to INPUT PARALLEL/SERIAL BUFFER) 52, and the digital waveform is converted to an analog waveform in analog processing/digital-analog converter (corresponding to ANALOG PROCESSING AND DAC) 53; then, after having been subjected to a filtering process, the resulting transmission data is transmitted to a telephone line.

Fig. 3 is a drawing that shows a construction of a receiving system of the communication device in accordance with the present invention. In this receiving system, the received data (corresponding to the above-mentioned

transmission data) is subjected to a filtering process in an analog processing/analog-digital converter (corresponding to ANALOG PROCESSING AND ADC in the Figure) 141, and the analog waveform is converted to a digital waveform; thereafter, this is subjected to an adaptive equalization process with respect to the time domain in a time domain equalizer (corresponding to TEQ) 142.

With respect to the data having been subjected to the adaptive equalization process, this is converted from serial data to parallel data in an input serial/parallel buffer (corresponding to INPUT SERIAL/PARALLEL BUFFER) 143, and this parallel data is subjected to a fast Fourier transform in a fast Fourier transform section (corresponding to FFT: Fast Fourier transform) 144; thereafter, this is subjected to an adaptive equalization process with respect to the frequency domain in a frequency domain equalizer (corresponding to FEQ) 145.

The data, which has been subjected to the adaptive equalization process with respect to the frequency domain, is subjected to a composite process (most likeliness composite method) and a tone ordering process in a constellation decoder/gain scaling (corresponding to CONSTELLATION DECODER AND GAIN SCALING) 146 and a tone ordering (corresponding to TONE ORDERING) 147 so that this is converted to serial data. Thereafter, this is subjected

to processes, such as a rate converting process by rate converters (corresponding to RATE-CONVERTER) 148, 149, a de-interleaving process in a deinterleave (corresponding to DEINTERLEAVE) 150, an FEC process and a de-scrambling process in forward error corrections (corresponding to DESCRAM & FEC) 151, 152, and a cyclic redundancy check in cyclic redundancy checks (corresponding to cyclic redundancy checks) 153, 154; thus, the received data is finally reproduced from a multiplex/synch control (corresponding to MUX/SYNC CONTROL) 155.

In the communication device as described above, the two paths are provided respectively in the receiving system and transmitting system, and by using these two paths properly or using these two paths at the same time, it is possible to realize a low-transmission delay and data communication with high rates.

In the communication device, the encoder shown in Fig. 1(a) is positioned at the constellation encoder/gain scaling 50 in the transmitting system, and the decoder shown in Fig. 1(b) is positioned at the constellation decoder/gain scaling 146 in the receiving system.

Operations of the encoder (transmitting system) and the decoder (receiving system) will now be explained in details. First, operations of the encoder which is shown in Fig. 1(a) will be explained. Fig. 4 shows a tone structure

(see (a)) in the multi-carrier modem system and a construction (see (b)) of the encoder that is applicable to the 4-bit constellation. Here, in the present embodiment, as illustrated in Fig. 4(a), with respect to the multi-value Quadrature Amplitude Modulation (QAM), for example, a 16 QAM system is adopted, and with respect to two tones in the multi-carrier, an encoding process is carried out. Moreover, in the encoder of the present embodiment, different from the conventional technique that executes a turbo encoding process on all the input data, the turbo encoding process is executed on the input data of the lower two bits as illustrated in Fig. 4(b), and with respect to the other upper bits, the input data, as it is, is outputted.

Here, the following description will discuss why only the lower two bits of the input data are subjected to the turbo encoding process. Fig. 5 is a drawing that shows the layout of signal points in various digital modulations; and more specifically, Fig. 5(a) shows the layout of signal points in the 4-phase shift keying (PSK) system, Fig. 5(b) shows the layout of signal points in the 16 QAM system, and Fig. 5(c) shows the layout of signal points in the 64 QAM system.

For example, when, in the layout of signal points in all the modulation systems, the received signal points are a or b positions, on the receiving side, normally, the data

having the most likelihood is estimated as the information bit list (transmission data) through a soft-judgment. In other words, the signal point having the closest distance to the received signal point is judged as the transmission data. However, at this time, for example, when attention is given to the received signal points a and b in Fig. 5, it is found that the four points, which are closest to the received signal point, have lower two bits represented by (0, 0) (0, 1) (1, 0) (1, 1), in any of the cases (corresponding to Figs. 5(a), (b) and (c)). Therefore, in the present embodiment, with respect to the lower two bits of the four signal points (the four points closest to received signal point) that are more likely to have degradation in the characteristics, the turbo encoding process having a superior error-correction capability is applied thereto, and a soft-judgment is carried out on the receiving side. In contrast, with respect to the other higher bits that are less likely to have degradation in the characteristics, these bits are outputted as they are, and a hard-judgment is made on the receiving side. Here, with respect to information bit lists u_3, u_4, u_5 and u_6, v_2, v_3, w_2 and w_3 respectively correspond to these.

Thus, in the present embodiment, the characteristics that might have degradation due to multi-valued levels can be improved, and since the turbo encoding process is carried

out only on the lower two bits of the received signal, it is possible to greatly reduce the amount of calculations as compared with the conventional technique that applies the turbo encoding process to all the bits.

The following description will discuss the operation of the turbo encoder 1 shown in Fig. 4(b) that carries out the turbo encoding process on the inputted lower two bits of the received data: u_1 and u_2. Fig. 6 is a drawing that shows the circuit construction of the turbo encoder 1. Reference numeral 21 denotes a first recursive system convolutional encoder. Reference numerals 22 and 23 denote interleavers. Reference numeral 24 denotes a second recursive system convolutional encoder, and reference numeral 25 denotes a deinterleaver. In the turbo encoder 1, the transmission data: u_{1k} and u_{2k} (with k representing the time) corresponding the information list, redundant data: u_{ak} obtained by encoding the transmission data through the process of the first recursive system convolutional encoder 21 and redundant data: u_{bk} obtained by encoding the transmission data that has been interleave-processed through the second recursive system convolutional encoder 24, and then allowing it to have the original time through the deinterleave process, are simultaneously outputted.

In this manner, in the present embodiment, the arrangement in which the di-interleaver 25 is added to the

second recursive convolutional encoder 24 as its following stage is used so that the times of the transmission data and the redundant data are made coincident with each other; thus, it is possible to efficiently carry out the calculating processes in the succeeding conversion 2.

Next, the conversion 2, which has received the two-bit transmission data: u_1 and u_2 and the two-bit redundant data: u_a and u_b from the turbo encoder 1, carries out calculating processes so as to provide uniform correction capabilities with respect to the transmission data on the receiving side.

For example, when the transmission data: u_1 and u_2 and the redundant data: u_a and u_b are transmitted without the conversion 2, on the receiving side, the original transmission data: u_1 and u_2 are estimated by using the received signals: u_a' and u_b' (' represents the received signal containing influences from noise and phasing in the transmission path). However, in this case, the received data: u_a' corresponding to the output of the first recursive system convolutional encoder 21 and the received data: u_b' outputted through each interleaver, the second recursive system convolutional encoder 24 and each di-interleaver are different in their error-correction capability; therefore, as illustrated in Fig. 7, they come to have a difference in the probability in bit errors. Therefore, in the present embodiment, the bit error rates on the receiving side are

uniformed by executing the following computation formulas:

$$v_1=u_2+u_a \quad \ldots (3)$$

$$v_0=u_2 \quad \ldots (4)$$

$$w_1=u_2+u_1+u_a+u_b \quad \ldots (5)$$

$$w_0=u_2+u_1 \quad \ldots (6)$$

Here, the above-mentioned v and w correspond to the respective tones shown in Fig. 4(a).

In this manner, in the present embodiment, the turbo encoder 1 and the conversion 2 are provided in the encoder so that the device can be applied to the communication using the multi-carrier modem system, and even when the constellation increases due to multi-valued levels in the modulation system, it is possible to reduce the amount of calculations, and also to achieve a good transmitting characteristics in the same manner as the conventional device. Here, in the present embodiment, the turbo encoder 1 and the conversion 2 are installed in the encoder; however, the present invention is not intended to be limited to this arrangement, and for example, when a difference in the bit error rate is permitted, the conversion 2 may be omitted, and it is still possible to reduce the amount of calculations. Moreover, in the present embodiment, the explanation has been given of the 16 QAM system as an example; however, the present invention is not intended to be limited by this, and even in the case of the application to the other modulation

systems (256 QAM system, etc.), the same effects can be obtained.

Next, operations of the decoder which is shown in Fig. 1(b) will be explained now. Here, in the present embodiment, for example, the 16 QAM system is adopted as the multi-value quadrature amplitude modulation (QAM), and the following description will discuss a case in which two tones in the multi-carrier are subjected to a decoding process. Moreover, in the encoder of the present embodiment, the turbo encoding process is carried out on the lower two bits of the received data, and the original transmission data is estimated by a soft-judgment, and with respect to the other upper bits, the original transmission data is estimated by carrying out a hard-judgment on the received data in the second judging device 19. Here, the received signals Lcy: V_0, V_1, V_2, V_3, W_0, W_1, W_2, W_3 are signals obtained by allowing the outputs on the transmitting side: v_0, v_1, v_2, v_3, w_0, w_1, w_2, w_3 to contain influences from noise and phasing due to the transmission path.

First, in the turbo encoder, upon receipt of the signals Lcy: V_0, V_1, W_0, W_1, the first decoder 11 calculates the logarithm likelihood ratio: $L(u_{1k}')$, $L(u_{2k}')$ (with k representing the time) of estimated bits: u_{1k}', u_{2k}' estimated by these received signals. Here, with respect to the decoder for calculating the logarithm likelihood ratio, for example,

the known maximum A-Posteriori (MAP algorithm) is often used; however, for example, the known Vitabi decoder may be used.

In this case, the logarithm likelihood ratio: $L(u_{1k}')$, $L(u_{2k}')$ are represented by the following equations:

$$L(u_{1k}')=L_{cy}+La(u_{1k})+Le(u_{1k})$$
$$=Ln\frac{Pr(u_{1k}'=1|\{Lcy\})}{Pr(u_{1k}'=0|\{Lcy\})} \quad \cdots\cdots (7)$$

$$L(u_{2k}')=L_{cy}+La(u_{2k})+Le(u_{2k})$$
$$=Ln\frac{Pr(u_{2k}'=1|\{Lcy\})}{Pr(u_{2k}'=0|\{Lcy\})} \quad \cdots\cdots (8)$$

Here, in the present embodiment, Le (u_{1k}), Le (u_{2k}) represent external information; La (u_{1k}), La (u_{2k}) represent pre-information that is external information preceding by one; $P_r(u_{1k}' = 1 | \{Lcy\})$ represents the post-probability of the estimated information bit: u_{1k}' being 1 upon receipt of all the lists of the received signals: {Lcy}; $P_r(u_{1k}' = 0 | \{Lcy\})$ represents the post-probability of the estimated information bit: u_{1k}' being 0; $P_r(u_{2k}' = 1 | \{Lcy\})$ represents the post-probability of the estimated information bit: u_{2k}' being 1 upon receipt of all the lists of the received signals: {Lcy}; and $P_r(u_{2k}' = 0 | \{Lcy\})$ represents the post-probability of the estimated information bit: u_{2k}' being

0. In other words, in equations (7) and (8), the probability of u_{2k}' being 1 with respect to the probability of u_{2k}' being 0, and the probability of u_{1k}' being 1 with respect to the probability of u_{1k}' being 0 are found.

Next, in the adder 12, external information for the second decoder 15 is calculated from the logarithm likelihood ratio that is the above calculation result. The external information: Le (u_{1k}), Le (u_{2k}) is represented as follows based upon the above-mentioned equations (7) and (8):

$$Le(u_{1k}) = L(u_{1k}') - Lcy - La(u_{1k}) \quad \ldots (9)$$

$$Le(u_{2k}) = L(u_{2k}') - Lcy - La(u_{2k}) \quad \ldots (10)$$

Here, in the first decoding process, since no pre-information is found, La (u_{1k}) = 0, and La (u_{2k}) = 0.

Next, in the interleavers 13 and 14, the signals are re-arranged based upon the received signal Lcy and the external information $Le(u_{1k})$, $Le(u_{2k})$. Then, in the second decoder 15, in the same manner as the first decoder 11, based upon the received signal Lcy and pre-information: $La(u_{1k})$, $La(u_{2k})$ that has been preliminarily calculated, the logarithm likelihood ratio: $L(u_{1k}')$, $L(u_{2k}')$ is calculated. Thereafter, in the adder 16, in the same manner as the adder 12, external information: $Le(u_{1k})$, $Le(u_{2k})$ is calculated by using equations (9) and (10). At this time, the external information, re-arranged by the deinterleave 17, is fed back to the first decoder 11 as the pre-information: $La(u_{1k})$,

$La(u_{2k})$.

Thereafter, in the above-mentioned turbo decoder, the above-mentioned processes are repeated predetermined times so that the logarithm likelihood ratio with higher precision is calculated; and lastly, the first judging device 18 judges the signals based upon the logarithm likelihood ratio so as to estimate the original transmission data. More specifically, for example, if the logarithm likelihood ratio shows "$L(u_{1k}') > 0$"; then, u_{1k}' is judged as 1, and if it shows "$L(u_{1k}') \leqq 0$"; then, u_{1k}' is judged as 0; in the same manner, if the logarithm likelihood ratio shows "$L(u_{2k}') > 0$"; then, u_{2k}' is judged as 1, and if it shows "$L(u_{2k}') \leqq 0$"; then, u_{2k}' is judged as 0. Here, with respect to the received signals Lcy: V_2, V_3, W_2, W_3 that are simultaneously received, they are hard-judged by using the second judging device 19.

In this manner, in the present embodiment, even when the constellation increases as the modulation system is multi-valued, the turbo decoder for carrying out a soft-judgment on the lower two bits of the received signal that are more susceptible to degradation in the characteristics and the judging device for carrying out a hard-judgment on the other bits of the received signal are provided; thus, it is possible to reduce the soft-judgment portions having a great amount of calculations, and also

to achieve a good transmitting characteristic in the same manner as the conventional device. Additionally, in the transmission path having random errors and burst errors in a mixed manner as described in the present embodiment, by adopting the R-S codes (Reed Solomon) for carrying out error corrections on a symbol basis and other known error-correction codes in a combined manner, it is possible to obtain a further superior transmission characteristic.

As described above, in accordance with the present invention, the communication device is made applicable to communication using the multi-carrier modem system, and is provided with a turbo encoding unit and a computing unit. Therefore, even when the constellation increases as the modulation system is multi-valued, it is possible to reduce the amount of calculations, and also to achieve a good transmitting characteristic in the same manner as the conventional device. Moreover, a soft-judgment is carried out on the lower two bits of the received signal that are more susceptible to degradation in the characteristics, and a hard-judgment is carried out on the other bits of the received signal. Therefore, even when the constellation increases as the modulation system is multi-valued, it is possible to provide a communication device which can reduce the soft-judgment portions having a great amount of calculations, and also achieve a good transmitting

characteristic in the same manner as the conventional device.

In accordance with the next invention, the communication device has an arrangement in which a deinterleave processing unit is added to the turbo encoding unit so that the times of the transmission data and redundant data are made coincident with each other. Therefore, it is possible to provide a communication device which can effectively carry out calculation processes in the succeeding computing unit.

In accordance with the next invention, even in a transmission path having random errors and burst errors in a mixed manner, since the R-S codes for carrying out error corrections on a symbol basis are combinedly used, it becomes possible to provide a communication device which can provide a further superior transmission characteristic.

In accordance with the next invention, the communication device is made applicable to communication using the multi-carrier modem system, and is provided with a turbo encoding unit and a computing unit. Therefore, even when the constellation increases as the modulation system is multi-valued, it is possible to reduce the amount of calculations, and also to achieve a good transmitting characteristic in the same manner as the conventional device.

In accordance with the next invention, the communication device has an arrangement in which a

deinterleave processing unit is added to the turbo encoding unit so that the times of the transmission data and redundant data are made coincident with each other. Therefore, it is possible to provide a communication device which can effectively carry out calculation processes in the succeeding computing unit.

In accordance with the next invention, when a difference in the bit error rate with respect to respective information bits is permitted, the computing unit may be omitted, and it is possible to further reduce the amount of calculations.

In accordance with the next invention, even in a transmission path having random errors and burst errors in a mixed manner, since the R-S codes for carrying out error corrections on a symbol basis are combinedly used, it becomes possible to provide a further superior transmission characteristic.

In accordance with the next invention, a soft-judgment is carried out on the lower two bits of the received signal that are more susceptible to degradation in the characteristics, and a hard-judgment is carried out on the other bits of the received signal; thus, even when the constellation increases as the modulation system is multi-valued, it is possible to provide a communication device which can reduce the soft-judgment portions having

a great amount of calculations, and also achieve a good transmitting characteristic in the same manner as the conventional device.

In accordance with the next invention, even in a transmission path having random errors and burst errors in a mixed manner, since the R-S codes for carrying out error corrections on a symbol basis are combinedly used, it becomes possible to provide a further superior transmission characteristic.

In accordance with the next invention, the communication made is made applicable to communication using the multi-carrier modem system, and is provided with a turbo encoding unit and a computing unit. Therefore, even when the constellation increases as the modulation system is multi-valued, it is possible to reduce the amount of calculations, and also to achieve a good transmitting characteristic in the same manner as the conventional method. Moreover, a soft-judgment is carried out on the lower two bits of the received signal that are more susceptible to degradation in the characteristics, and a hard-judgment is carried out on the other bits of the received signal. Therefore, even when the constellation increases as the modulation system is multi-valued, it is possible to provide a communication method which can reduce the soft-judgment portions having a great amount of calculations, and also

achieve a good transmitting characteristic in the same manner as the conventional method.

In accordance with the next invention, a deinterleave processing step is added to the turbo encoding step so that the times of the transmission data and redundant data are made coincident with each other; therefore, it is possible to provide a communication method which can effectively carry out calculation processes in the succeeding computing step.

In accordance with the next invention, even in a transmission path having random errors and burst errors in a mixed manner, since the R-S codes for carrying out error corrections on a symbol basis are combinedly used, it becomes possible to provide a communication method which achieve a further superior transmission characteristic.

INDUSTRIAL APPLICABILITY

As described above, the communication device in accordance with the present invention is effectively applied to data communications using the DMT (Discrete Multi Tone) modem system and the OFDM (Orthogonal Frequency Division Multiplex) modem system, and in particular, to xDSL communication systems such as the xDSL communication systems including an ADSL (Asymmetric Digital Subscriber Line) communication system and an HDSL (high-bit-rate Digital Subscriber Line) communication system that execute a

high-speed digital communication with several mega bits/second by using the existing telephone lines.

CLAIMS

1. A communication device, which uses turbo codes as error-correction codes, comprising:

a turbo encoding unit which carries out a turbo encoding process on lower bits of a predetermined number in transmission data to output information bits in accordance with the predetermined number and first and second redundant bits that have been convolutionally encoded in different sequences;

a computing unit which carries out calculations for uniforming error-correction capabilities on the respective information bits by using the information bits of the predetermined number and the redundant bits to output the results of the calculations and the other bits in the transmission data as the results of the encoding process;

a first decoding unit which extracts the information bits and the first redundant bits from the lower bits of the predetermined number in the received signal, and makes a soft-judgment based upon the results of the extraction and a soft judgment output that is an output preceding by one given as preliminary information (in some cases, not given);

a second decoding unit which extracts the information bits and the second redundant bits, makes a soft-judgment based upon the results of the extraction and the

soft-judgment output from said first decoding unit, and informs said first decoding unit of the results thereof as the soft-judgment output preceding by one;

a first judging unit which executes the soft-judgment by said first decoding unit and said second decoding unit a predetermined times repeatedly, and then estimates the original information bit based upon the soft-judgment output of said second decoding unit; and

a second judging unit which makes a hard-judgment on the other bits in the received signal to estimate the original information bits.

2. The communication device according to claim 1, wherein said turbo encoding unit includes a deinterleave processing unit for carrying out a de-interleaving process on one group of the redundant bits that have been encoded after the interleave process to output the respective information bits and the redundant bits with the times being coincident with each other.

3. The communication device according to claim 1, wherein Reed Solomon codes and turbo codes are used combinedly, and on the transmitting side, the turbo encoding is carried out after the Reed Solomon encoding, while on the receiving side, the Reed Solomon codes are decoded after decoding the turbo

codes.

4. A communication device comprising an encoder that uses turbo codes with the interleave process being incorporated into the encoding process, and outputs results of the encoding process,

said encoder includes,

a turbo encoding unit which receives transmission data constituted by a plurality of bits, and carries out a turbo encoding process on lower bits of a predetermined number in transmission data to output information bits in accordance with the predetermined number, first redundant bits that have been obtained by convolutionally encoding the information bits and second redundant bits that have been obtained by convolutionally encoding the information bits after the interleave process; and

a computing unit which carries out calculations for uniforming error-correction capabilities on the respective information bits by using the information bits of the predetermined number and the redundant bits,

wherein the results of the calculations and the other bits in the transmission data are outputted as the results of the encoding process.

5. The communication device according to claim 4, wherein said turbo encoding unit includes a deinterleave processing unit which carries out a de-interleaving process on the second redundant bits,

wherein the respective information bits, the first redundant bits and the second redundant bits that have been subjected to the de-interleaving process are outputted with the times being coincident with each other.

6. The communication device according to claim 4, wherein Reed Solomon codes and turbo codes are used combinedly and the turbo encoding is carried out after the Reed Solomon encoding.

7. A communication device comprising an encoder that uses turbo codes with the interleave process being incorporated into the encoding process, and outputs results of the encoding process,

said encoder includes a turbo encoding unit which receives transmission data constituted by a plurality of bits, and carries out a turbo encoding process on lower bits of a predetermined number in transmission data to output information bits in accordance with the predetermined number, first redundant bits that have been obtained by convolutionally encoding the information bits and second

redundant bits that have been obtained by convolutionally encoding the information bits after the interleave process,

wherein, in addition to the respective information bits and the first and second redundant bits, the other bits in the transmission data are outputted as the results of the encoding process.

8. The communication device according to claim 7, wherein Reed Solomon codes and turbo codes are used combinedly and the turbo encoding is carried out after the Reed Solomon encoding.

9. A communication device comprising a decoder that decodes a received signal that has been turbo encoded by using a soft judgment,

said decoder including,

a first decoding unit which extracts information bits and first redundant bits that have been convolutionally encoded from the lower bits of the predetermined number in the received signal, and makes a soft-judgment based upon the results of the extraction and a soft judgment output that is an output preceding by one given as preliminary information (in some cases, not given);

a second decoding unit which extracts the information bits in accordance with the number of outputs

on the encoder side and the second redundant bits that have been convolutionally encoded in a method different from the first redundant bits from the lower bits in the predetermined number in the received signal, makes a soft-judgment based upon the results of the extraction and the soft-judgment output from said first decoding unit, and informs said first decoding unit of the results thereof as the soft-judgment output preceding by one;

a first judging unit which executes the soft-judgment by said first decoding unit and said second decoding unit a predetermined times repeatedly, and then estimates the original information bit based upon the soft-judgment output of said second decoding unit; and

a second judging unit which makes a hard-judgment on the other bits in the received signal to estimate the original information bits.

10. The communication device according to claim 9, wherein, when Reed Solomon codes and turbo codes are used combinedly on the transmitting side, the Reed Solomon codes are decoded after decoding the turbo codes.

11. A communication method, which uses turbo codes as error-correction codes, the method comprising:

a turbo encoding step of carrying out a turbo encoding

process on lower bits of a predetermined number in transmission data to output information bits in accordance with the predetermined number and first and second redundant bits that have been convolutionally encoded in different sequences;

a computing step of carrying out calculations for uniforming error-correction capabilities on the respective information bits by using the information bits of the predetermined number and the redundant bits to output the results of the calculations and the other bits in the transmission data as the results of the encoding process;

a first decoding step of extracting the information bits and the first redundant bits from the lower bits of the predetermined number in the received signal so as to make a soft-judgment based upon the results of the extraction and a soft judgment output that is an output preceding by one given as preliminary information (in some cases, not given);

a second decoding step of extracting the information bits and the second redundant bits so as to make a soft-judgment based upon the results of the extraction and the soft-judgment output from the first decoding step, thereby making the results thereof as the soft-judgment output preceding by one;

a first judging step of executing the soft-judgment

by the first decoding step and the second decoding step a predetermined times repeatedly, and then estimating the original information bit based upon the soft-judgment output of the second decoding step; and

a second judging step of making a hard-judgment on the other bits in the received signal to estimate the original information bits.

12. The communication method according to claim 11, wherein the turbo encoding step includes a deinterleave processing step of carrying out a de-interleaving process on one group of the redundant bits that have been encoded after the interleave process,

wherein the respective information bits and the redundant bits are outputted with the times being coincident with each other.

13. The communication method according to claim 11, wherein Reed Solomon codes and turbo codes are used combinedly, and on the transmitting side, the turbo encoding is carried out after the Reed Solomon encoding, while on the receiving side, the Reed Solomon codes are decoded after decoding the turbo codes.

ABSTRACT

A communication device is provided with a turbo encoder (1) which carries out a turbo encoding process on the lower two bits of transmission data so as to output information bits of two bits and redundant bits of two bits, a conversion (2) which carries out calculations so as to uniform error-correction capabilities on respective information bits by using the output, decoders (11 to 18) which carries out a soft-judgment on the lower two bits of the received signal that are susceptible to degradation in the characteristics so as to estimate the original transmission data, and a second judging device (19) which carries out a hard-judgment on the other bits in the received signal so as to estimate the original transmission data.

FIG.1

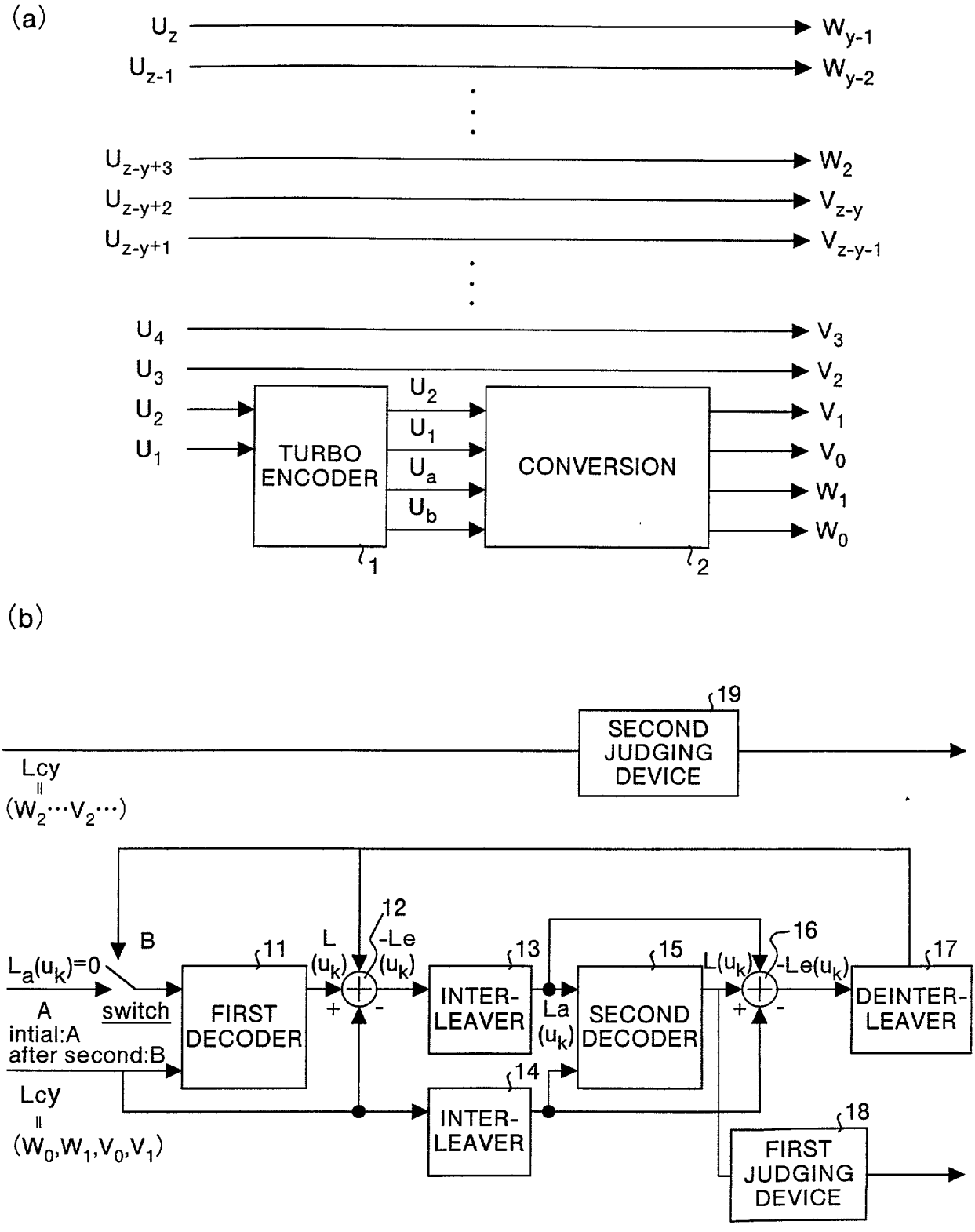

(a)
U_z
U_{z-1}
U_{z-y+3}
U_{z-y+2}
U_{z-y+1}
U_4
U_3
U_2
U_1
TURBO ENCODER
1
U_2
U_1
U_a
U_b
CONVERSION
2
W_{y-1}
W_{y-2}
W_2
V_{z-y}
V_{z-y-1}
V_3
V_2
V_1
V_0
W_1
W_0
(b)
19
SECOND JUDGING DEVICE
Lcy
$(W_2 \cdots V_2 \cdots)$
B
$L_a(u_k)=0$
A
switch
intial:A
after second:B
Lcy
(W_0,W_1,V_0,V_1)
11
FIRST DECODER
L (u_k)
12
-Le (u_k)
13
INTER-LEAVER
14
INTER-LEAVER
La (u_k)
15
SECOND DECODER
$L(u_k)$
16
$-Le(u_k)$
17
DEINTER-LEAVER
18
FIRST JUDGING DEVICE

FIG.2

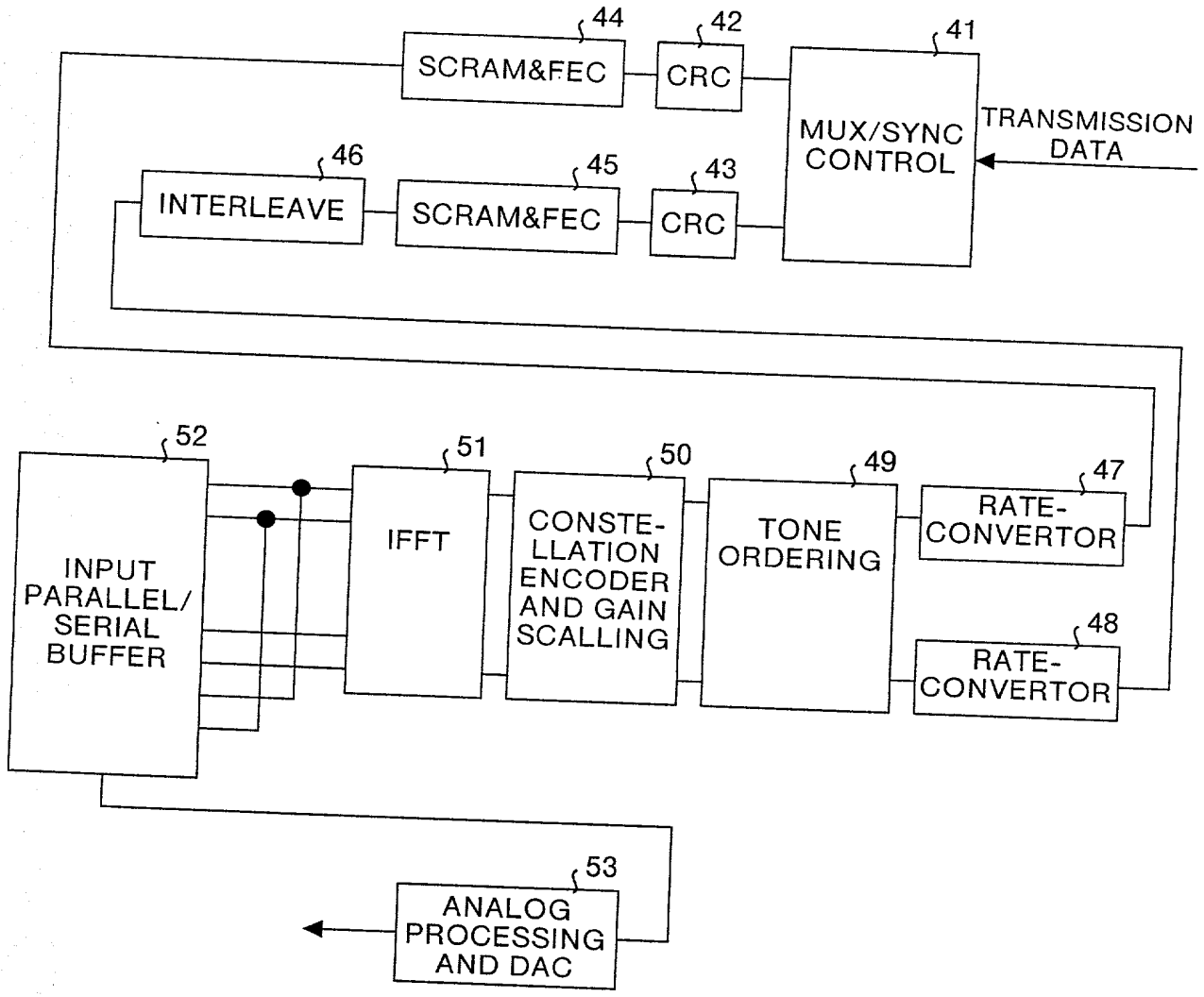

44
SCRAM&FEC
42
CRC
41
MUX/SYNC CONTROL
TRANSMISSION DATA
46
INTERLEAVE
45
SCRAM&FEC
43
CRC
52
INPUT PARALLEL/ SERIAL BUFFER
51
IFFT
50
CONSTE-LLATION ENCODER AND GAIN SCALLING
49
TONE ORDERING
47
RATE-CONVERTOR
48
RATE-CONVERTOR
53
ANALOG PROCESSING AND DAC

FIG.3

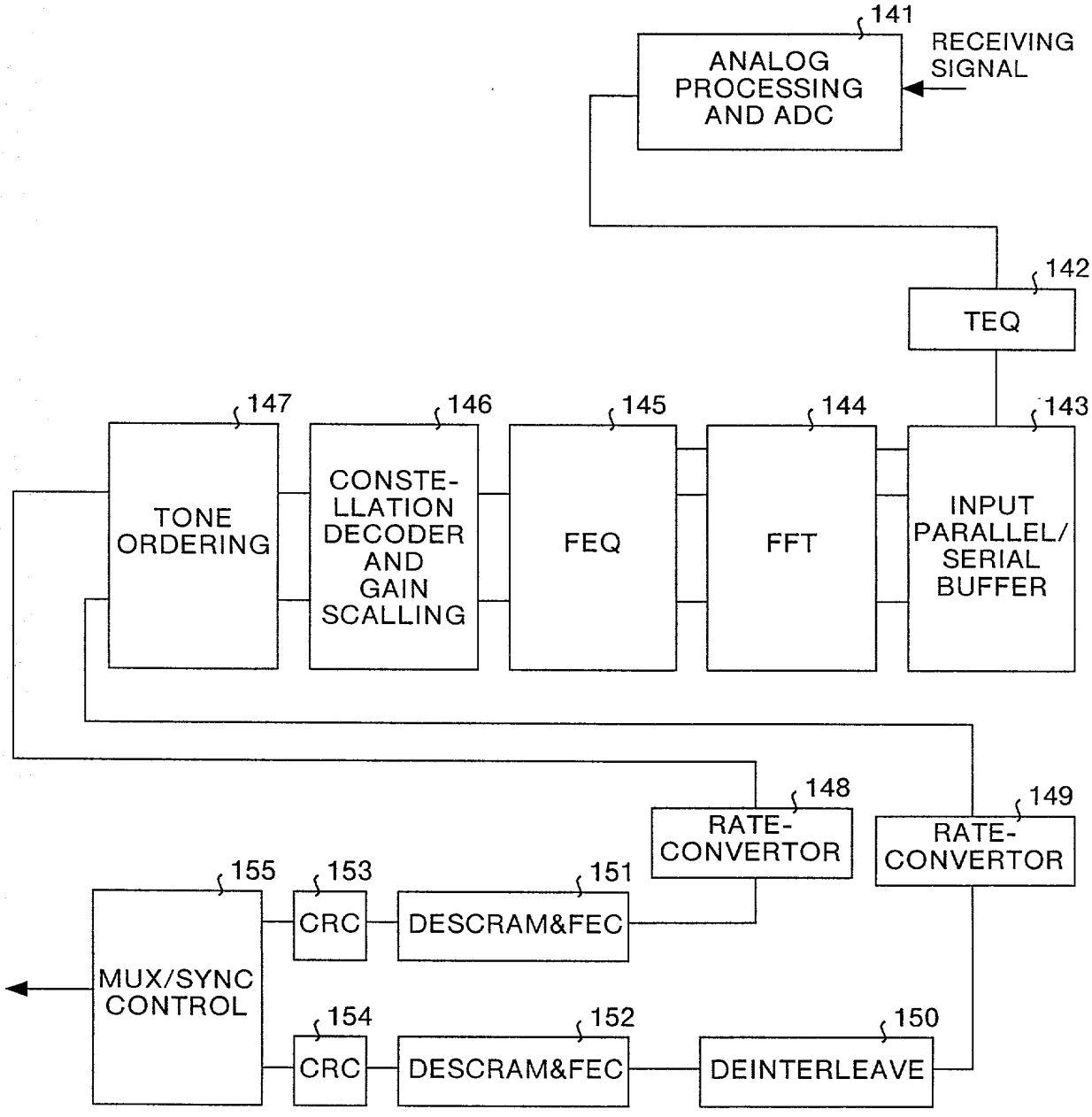

141
ANALOG PROCESSING AND ADC
RECEIVING SIGNAL
142
TEQ
147
TONE ORDERING
146
CONSTE-LLATION DECODER AND GAIN SCALLING
145
FEQ
144
FFT
143
INPUT PARALLEL/ SERIAL BUFFER
148
RATE-CONVERTOR
149
RATE-CONVERTOR
155
MUX/SYNC CONTROL
153
CRC
151
DESCRAM&FEC
154
CRC
152
DESCRAM&FEC
150
DEINTERLEAVE

FIG.4

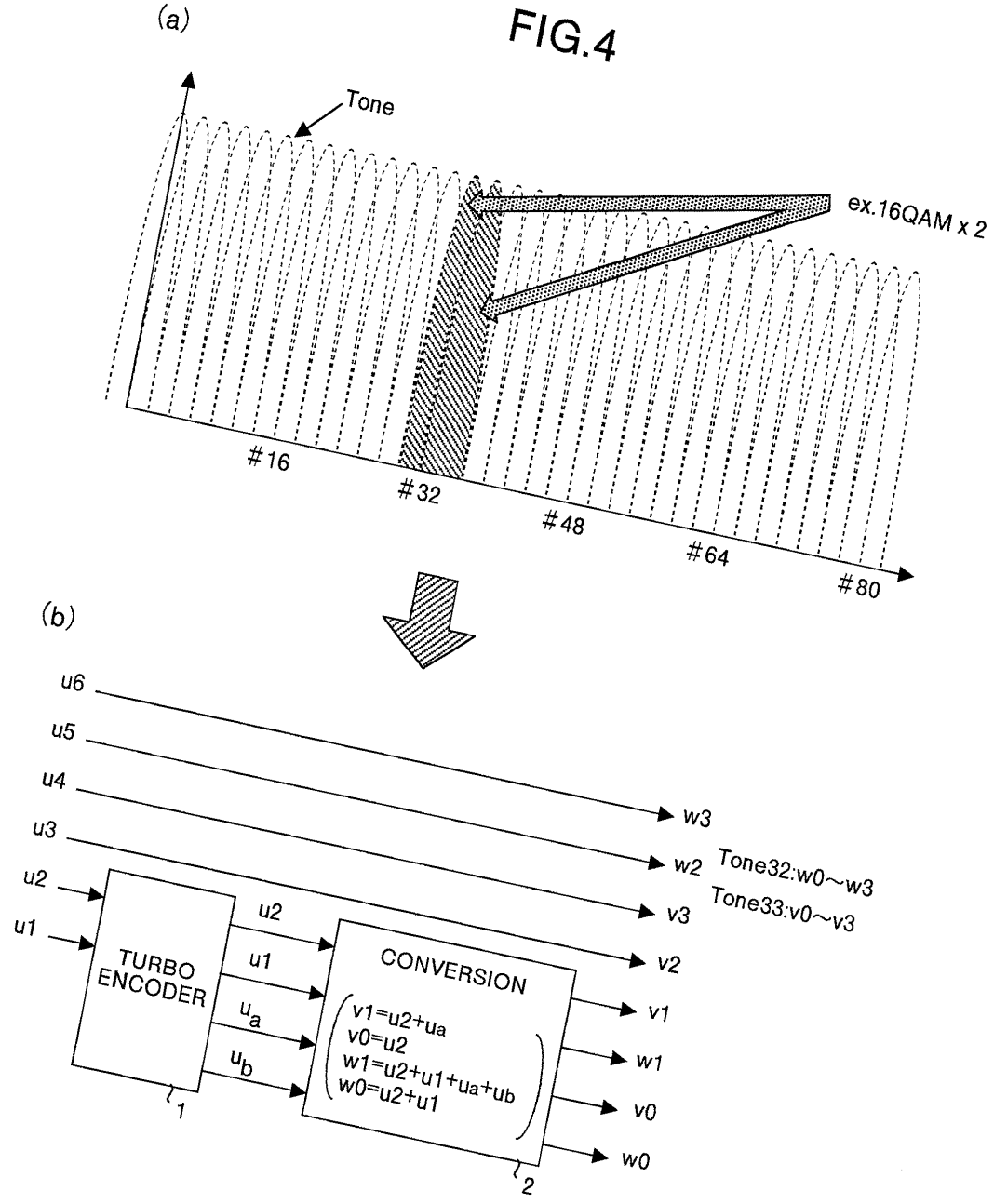
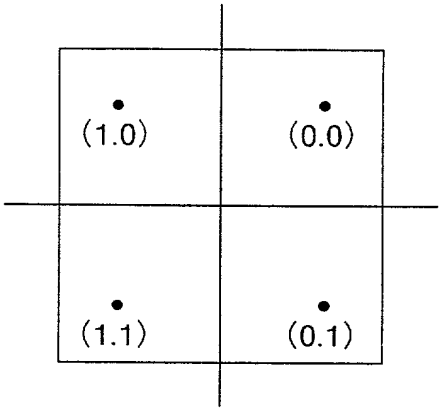
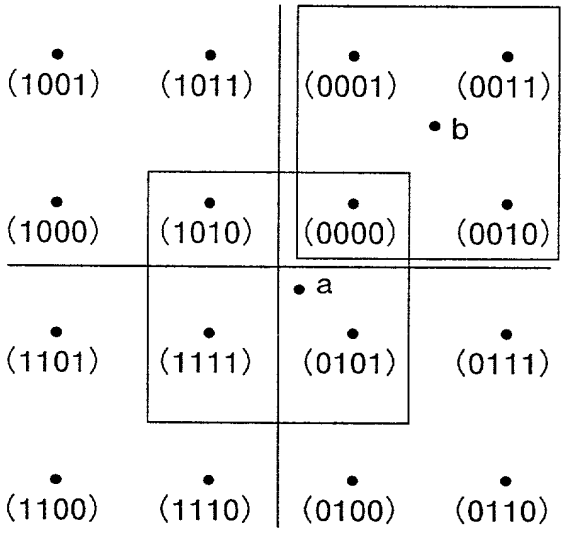

(a)
Tone
ex.16QAM x 2
#16
#32
#48
#64
#80
(b)
u6
u5
u4
u3
u2
u1
w3
w2
v3
v2
Tone32:w0~w3
Tone33:v0~v3
TURBO ENCODER
1
u2
u1
ua
ub
CONVERSION
v1=u2+ua
v0=u2
w1=u2+u1+ua+ub
w0=u2+u1
2
v1
w1
v0
w0

FIG.5

(a)


(1.0)
(0.0)
(1.1)
(0.1)

(b)


(1001)
(1011)
(0001)
(0011)
b
(1000)
(1010)
(0000)
(0010)
a
(1101)
(1111)
(0101)
(0111)
(1100)
(1110)
(0100)
(0110)

(c)

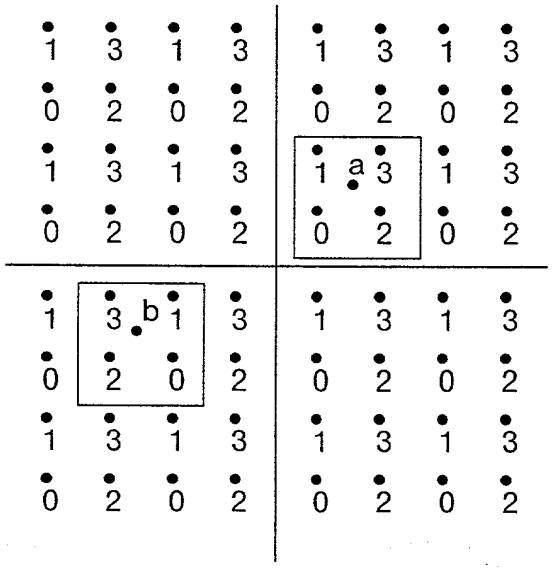

a
b

FIG.6

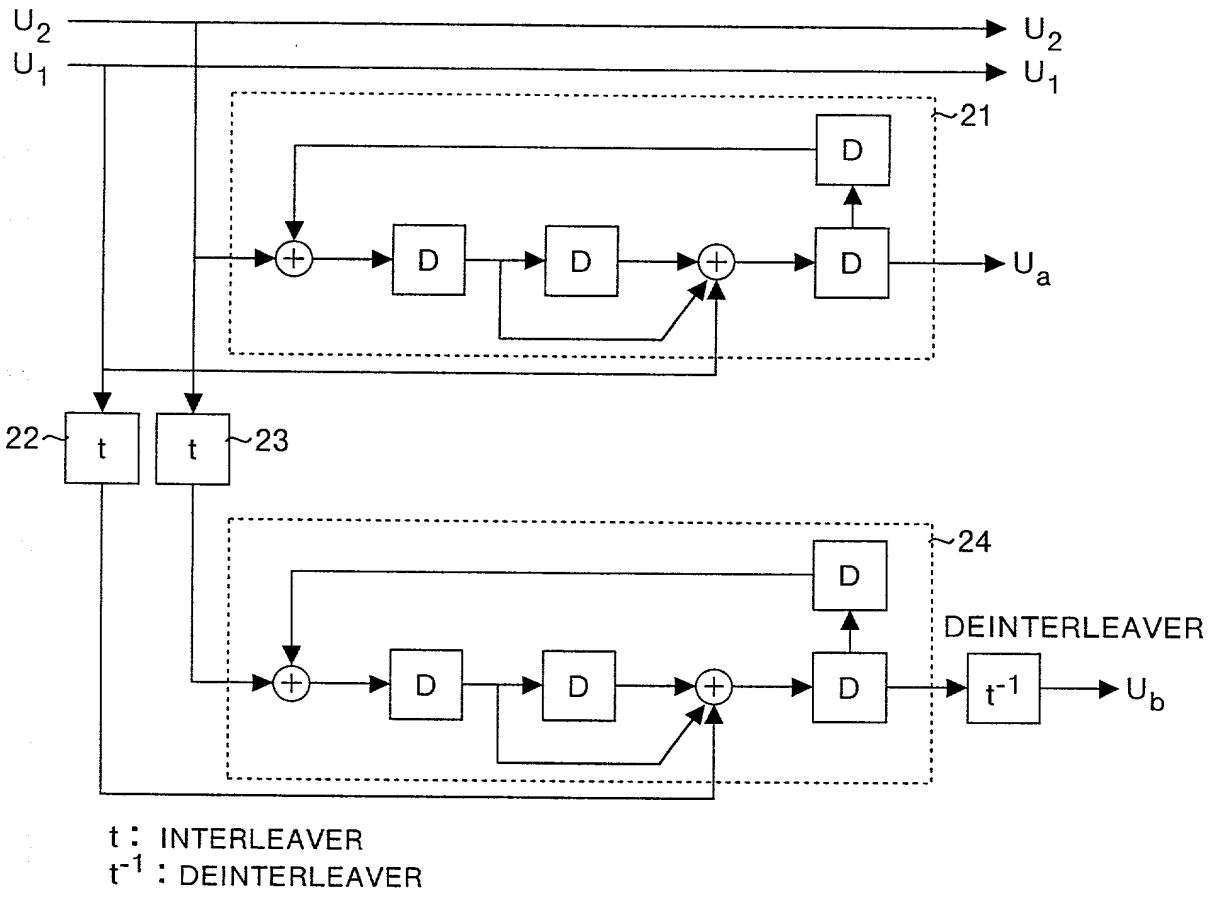

U2
U1
U2
U1
21
D
D
D
D
Ua
22
t
t
23
24
D
D
D
D
DEINTERLEAVER
t-1
Ub
t : INTERLEAVER
t-1 : DEINTERLEAVER

FIG.7

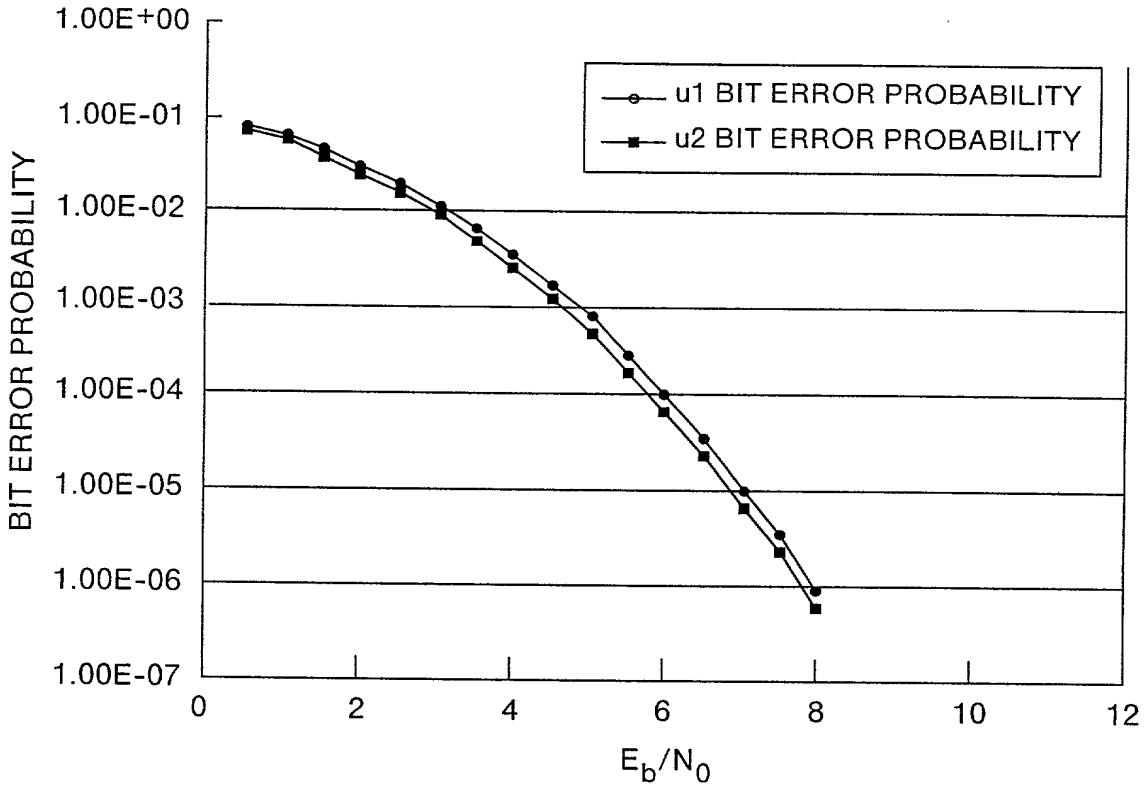
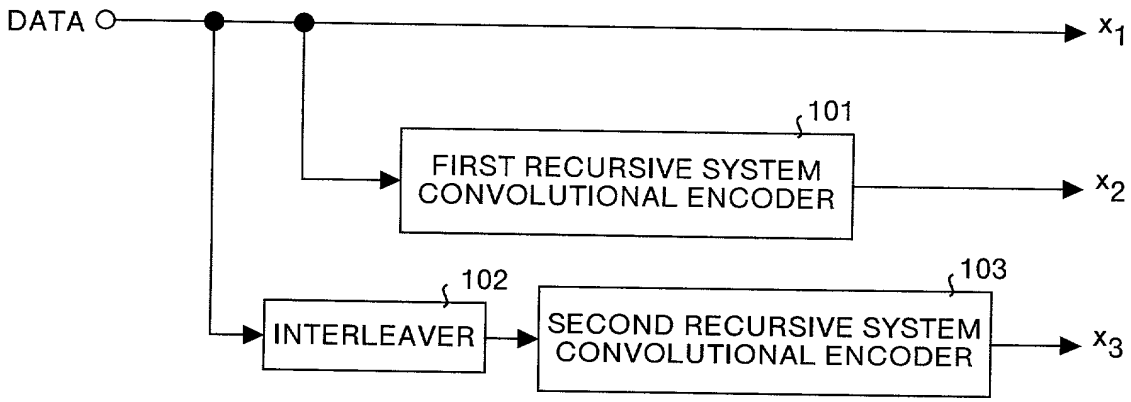

1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
BIT ERROR PROBABILITY
u1 BIT ERROR PROBABILITY
u2 BIT ERROR PROBABILITY
0
2
4
6
8
10
12
E_b/N_0

FIG.8

(a)


DATA
x_1
101
FIRST RECURSIVE SYSTEM CONVOLUTIONAL ENCODER
x_2
102
INTERLEAVER
103
SECOND RECURSIVE SYSTEM CONVOLUTIONAL ENCODER
x_3

(b)

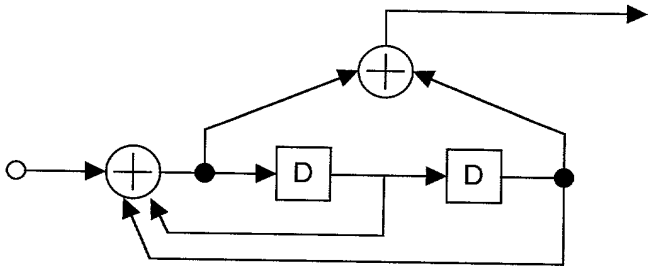
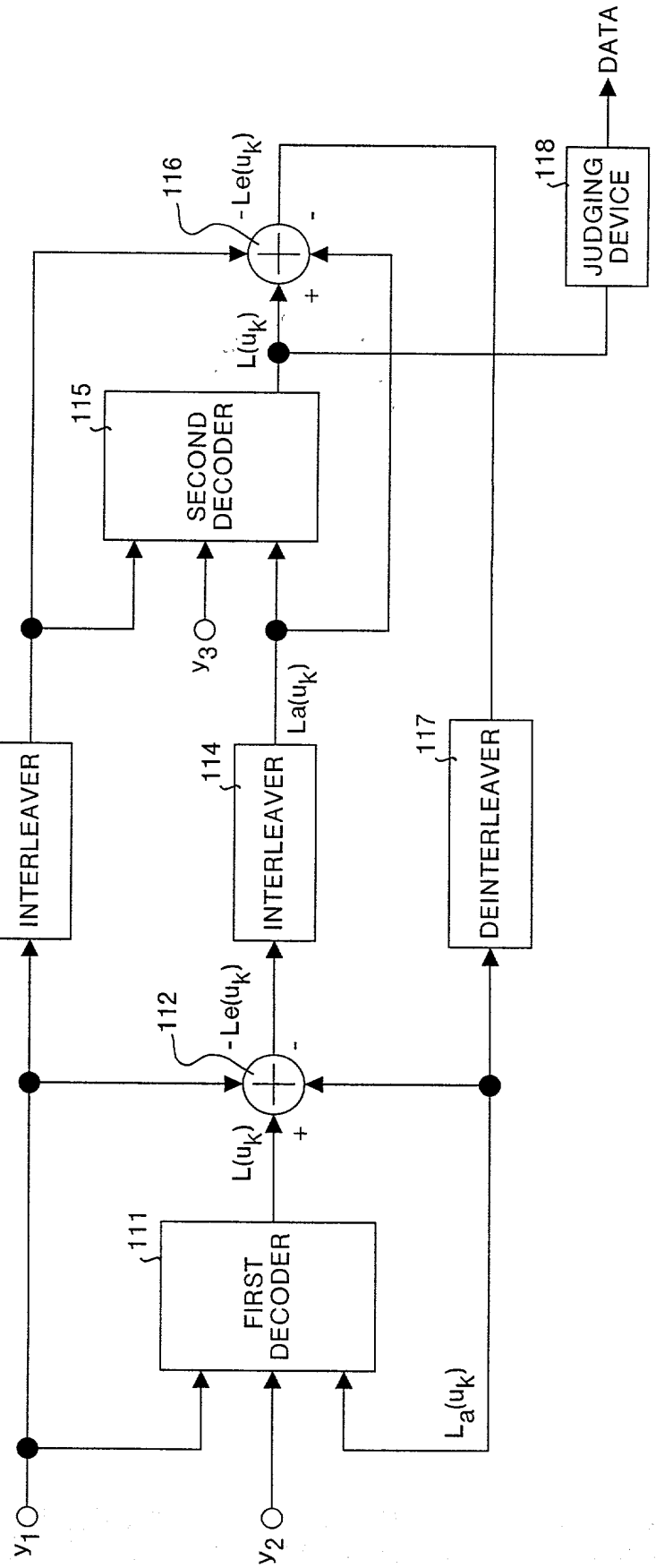

D
D

FIG.9


DATA
JUDGING DEVICE
118
116
$-Le(u_k)$
$L(u_k)$
SECOND DECODER
115
y_3
$La(u_k)$
INTERLEAVER
113
INTERLEAVER
114
DEINTERLEAVER
117
112
$-Le(u_k)$
$L(u_k)$
FIRST DECODER
111
y_1
y_2
$L_a(u_k)$

Declaration and Power of Attorney For Patent Application

特許出願宣言書

Japanese Language Declaration

私は、下欄に氏名を記載した発明者として、以下のとおり宣言する：

As a below named inventor, I hereby declare that:

私の住所、郵便の宛先および国籍は、下欄に氏名に続いて記載したとおりであり、

My residence, post office address and citizenship are as stated below next to my name,

名称の発明に関し、請求の範囲に記載した特許を求める主題の本来の、最初にして唯一の発明者である（一人の氏名のみが下欄に記載されている場合）か、もしくは本来の、最初にして共同の発明者である（複数の氏名が下欄に記載されている場合）と信じ、

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

METHOD OF AND DEVICE FOR

COMMUNICATION

その明細書を
（該当する方に印を付す）

the specification of which

(check one)

☐ ここに添付する。

☒ is attached hereto.

☐ _____ 日に出願番号
第 _____ 号として提出し、
_____ 日に補正した。
（該当する場合）

☐ was filed on _____
as United States Application Number or
PCT International Application Number
_____ and was amended on
_____ (if applicable).

私は、前記のとおり補正した請求の範囲を含む前記明細書の内容を検討し、理解したことを陳述する。

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私は、連邦規則法典第37部第１章第56条　　項に従い、本願の審査に所要の情報を開示すべき義務を有することを認める。

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56.

Japanese Language Declaration

2611-0148P

私は、合衆国法典第35部第119 条にもとづく下記の外国特許出願または発明者証出願の外国優先権利益を主張し、さらに優先権の主張に係わる基礎出願の出願日前の出願日を有する外国特許出願または発明者証出願を以下に明記する：

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior foreign applications
先の外国出願

(Number) (番 号)	(Country) (国 名)	(Day/Month/Year Filed) (出願の年月日)	Priority claimed 優先権の主張 Yes あり	No なし
11-308750	Japan	29/Oct./1999	☒	☐
			☐	☐
			☐	☐

私は、合衆国法典第35部第120 条にもとづく下記の合衆国特許出願の利益を主張し、本願の請求の範囲各項に記載の主題が合衆国法典第35部第112 条第１項に規定の態様で先の合衆国出願に開示されていない限度において、先の出願の出願日と本願の国内出願日またはＰＣＴ国際出願日の間に公表された連邦規則法典第37部第１章第56条　　項に記載の所要の情報を開示すべき義務を有することを認める：

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56　　which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.) (出願番号)	(Filing Date) (出願日)	(現　況) (特許済み、係属中、放棄済み)	(Status) (patented, pending, abandoned)

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Japanese Language Declaration

2611-0148P

委任状：私は、下記発明者として、以下の代理人をここに選任し、本願の手続を遂行すること並びにこれに関する一切の行為を特許商標庁に対して行うことを委任する。
（代理人氏名および登録番号を明記のこと）

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (*list name and registration number*)

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Joseph A. Kolasch	(Reg. No. 22,463)	James M. Slattery	(Reg. No. 28,380)
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同発明者の署名 日付	Inventor's signature Wataru Matsumoto Date May 18, 2001
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国籍	Citizenship Japanese
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同第2発明者の署名 日付	Second inventor's signature Yoshikuni Miyata Date May 18, 2001
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（第六またはそれ以降の共同発明者に対しても同様な情報および署名を提供すること。）

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(2-92)

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